RELATING WILDLAND FIRE TO DEFOLIATION AND MORTALITY IN PINE[1]

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ABSTRACT.--Numerous accounts in the literature demonstrate that the effects of fire on North American pines are highly variable. In some cases trees with severe crown scorch survive and grow more rapidly, while in other cases extensive mortality results. Three of the most important factors affecting a tree's response to fire are the timing of defoliation, level of defoliation, and species differences in bud development. An ongoing field study designed to assess the importance of defoliation level and timing upon southern pine survival and growth is described.

INTRODUCTION

The literature contains numerous accounts of fire and its effects on the pine forests of North America. This extensive data base spans a period of more than 100 years and ranges from simple recollections to replicated laboratory studies. The full range of plant responses to all but the most intense fires can be found. Differing responses to fire are caused by a host of factors, many of which are mentioned in Wade and Johansen (1986). We speculate that three of the most important factors affecting survival and subsequent growth are the timing of defoliation, level of defoliation, and species differences in bud development. These factors are discussed in this paper. In addition, an ongoing field study designed to assess the importance of defoliation upon southern pine survival and growth is outlined. Growth differences 3 months after defoliation and visual impressions 6 months after defoliation are described.

BACKGROUND

Plant tissue is killed when its lethal time-temperature combination is reached. A commonly accepted temperature for near-instantaneous death is 140°F (Byram 1948). Temperatures of 115°F will also kill plant cells if they are sustained for several hours according to work reviewed by Hare (1961) and McArthur (1980), but prescribed burns are not likely to elevate temperatures for that long a period. Yellow to bronze foliage immediately after a fire is a sure indicator that a lethal heat dose was applied; the discolored needles are in fact dead. Charred or partially consumed needles indicate that the ignition temperature of cellulose (about 450° F) was reached. These mortality and ignition thresholds are increasingly likely to be met as the ambient air temperature increases. Summer fires often occur when ambient temperatures are 30 to 60°F higher than those associated with winter fires. Moreover, temperatures of the upper tree crowns can be higher than the surrounding air due to solar heating. Thus, little additional heat is required to raise needles to their lethal temperature threshold during summer burns.

Even with cool winter temperatures, southern pines can suffer complete crown scorch, but they also routinely survive provided they are larger than about 2 inches d.b.h. and no foliage is actually consumed. Crown damage from fires during the growing season is generally more severe, and its consequences are more serious. We believe this differential survival between seasons is primarily a function of bud-kill. When bud-kill is combined with defoliation, a much more life-threatening situation exists. Crown scorch does not automatically signify bud-kill in the four major southern pine species because the buds of these species, especially longleaf (*Pinus palustris* Mill.), are thicker than the needles. Because the rate of temperature rise is inversely proportional to thickness, either higher temperatures or lower sustained temperatures are necessary to kill the buds of such species. There are no obvious signs to enable an observer on the ground to differentiate between completely scorched trees with and without bud damage if needles have not been consumed.

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For species with needles at least equal to their buds in thickness, crown scorch is a reliable indicator of crown kill. These species also tend to have fine branches which are easily heat-killed, even though the branch tips may temporarily survive because the needle clusters form a protective sheath around them. Regardless of the protective mechanism, a given tree is much more likely to suffer crown damage during a summer fire because of higher ambient temperatures.

BUD DEVELOPMENT AND TIMING OF DEFOLIATION

Most northern temperate zone pines have preformed buds. That is, their winter buds contain all the unexpanded shoots for the following season's growth. These species are thus confined to a single growth flush each year. After dormancy is broken in the spring, the shoots elongate fairly rapidly (1 to 2 months) and then form next year's buds.

The four major southern pine species, on the other hand, undergo multiple flushes because their winter buds do not contain all the shoot primordia for the following growing season. When dormancy is broken in the spring, the terminal bud expands into a shoot and a second bud forms at the apex of the shoot. That bud elongates to extend the initial shoot, and another bud is formed. Southern pines generally undergo three to four flushes during the growing season although as many as seven have been recorded in the literature (Wakeley and Marrero 1958). Depending upon species and environmental conditions, the buds that form after the first flush may open immediately upon formation or after varying periods of time (Romberger 1963). Defoliation, especially early in the growing season, has been shown to stimulate the rapid opening of buds regardless of whether the species has preformed buds or is multinodal. Later in the summer, however, defoliation will not elicit the same response--apparently due to a shortening of the photoperiod, so the defoliated tree remains naked until the following spring.

Complete defoliation of any evergreen has dire consequences with damage a function of the length of time the tree is without foliage. It has been demonstrated that root system recovery after defoliation is directly related to the length of time the trees are defoliated. Kozlowski (1971) presents a synopsis of the evidence that shows root growth is governed by the supply of photosynthetic products and growth-regulating hormones from the crown. The reduction in live root mass following severe insect defoliation is well documented (Swain and Craighead 1924, Redmond 1959, Gregory and Wargo 1986). However, published data relating fire defoliation to growth responses and mortality are, at first glance, without pattern and in some instances appear to be contradictory. Separation of this literature by season of defoliation and bud development markedly clarifies the picture. In species with preset buds, complete defoliation any time during the growing season will result in death (e.g. Craighead 1940, O'Neil 1962, Methven 1971), while in the multinodal southern pines, the damage is most severe following defoliation late in the growing season (Allen 1960, Beal 1942, Bruce 1956, Wade and Ward 1975).

FIELD STUDY

In an attempt to determine the importance of season and level of defoliation and to assess the magnitude and duration of any growth responses in southern pine, we installed a defoliation study in 4-year-old loblolly pine (*P. taeda* L.) and slash pine (*P. elliottii* Engelm.) plantations. A factorial experiment (4x5) with a random mixed block design was established at 4 locations (2 per species). Fifteen blocks were used at each location. One of five levels of defoliation (0, 33, 66, 95, or 100 percent) and one of four seasons of defoliation (January, April, July, or October) were assigned to each of 20 trees within a block. Needles were hand removed during the first 2 weeks of each treatment month.

Pretreatment d.b.h. and height were measured on all 1200 trees during the 1985-86 dormant season. The April, July, and October defoliation took place as scheduled. While applying the October treatments, we formed several visual impressions regarding the trees defoliated earlier in the growing season. Those trees defoliated 6 months previously (April) had all refoliated, undergone several flushes, and looked healthy. The trees defoliated in July, on the other hand, had all refoliated but had not undergone as many post-defoliation flushes and, thus, had sparser crowns. In many instances the needles on the July trees also appeared to be somewhat chlorotic.

Heights and d.b.h.'s of the trees defoliated in April were remeasured in July. Growth differences between defoliation levels are striking (Table 1). Three-month diameter growth was commensurate with the level of defoliation. Diameter growth of the completely defoliated trees was 34 and 36 percent of the non-defoliated trees for loblolly and slash pine, respectively. The same general trend was found in height growth, though species differences were greater--62 percent in slash pine and 45 percent in loblolly pine. In three of the four locations, trees that had the lower 33 percent of their crowns removed outgrew the controls in height during the first half of the growing season. All trees are scheduled for remeasurement during the 1986-87 and 1987-88 dormant seasons.

Table 1.—Three-month growth responses of southern pine subjected to five levels of defoliation during early April 1986.

Location	DBH Percent Defoliation					Height Percent Defoliation				
	0	33	66	95	100	0	33	66	95	100
Slash pine GA For. Comm. Waycross, GA	100	100	73	43	46	100	99	85	79	63
Slash pine Union Camp Corp. Palatka, FL	100	82	44	35	26	100	100	99	67	61
Loblolly pine Int. Paper Co. Bainbridge, GA	100	79	70	47	34	100	100	94	67	53
Loblolly pine Westvaco Corp. Branchville, SC	100	82	65	40	32	100	102	77	59	38

[1]Expressed as a percentage of the growth of trees with no defoliation.

SUMMARY

All study trees, including those completely defoliated at the beginning of the growing season or halfway through the season, had refoliated and were alive as of early October. However, both diameter and height growth had been severely retarded, especially with the more severe levels of defoliation. At this time we can only speculate on future growth losses or mortality, although some of the July defoliated trees show signs of trauma in the form of yellowing in the new-growth needles. When the full impact of these crown damage treatments has been assessed, the results will have obvious implications in the scheduling of prescribed fire as well as in interpreting literature reports on "fire treatment" used to measure fire effects.

LITERATURE CITED

Allen, Peter H. 1960. Scorch and mortality after a summer burn in loblolly pine. Res. Note SE-144. Asheville, NC: U.S. Department of Agriculture, Forest Service, Franklin Research Center. 2 pp.

Beal, J.A. 1942. Mortality of reproduction defoliated by the Red-headed Pine Sawfly (Neodiprion lecontei Fitch). Journal of Forestry 40(7):562-563.

Bruce, David. 1956. Effect of defoliation on growth of longleaf pine seedlings. Forest Science 2(1):31-35.

Byram, George M. 1948. Vegetation temperature and fire damage in the southern pines. Fire Control Notes 9(4):34-36.

Craighead, F.C. 1940. Some effects of artificial defoliation on pine and larch. Journal of Forestry 38(11):885-888.

Gregory, Robert A. and Philip M. Wargo. 1986. Timing of defoliation and its effect on bud development, starch reserves, and sap sugar concentration in sugar maple. Canadian Journal of Forestry Research 16(1):10-17.

Hare, Robert C. 1961. Heat effects on living plants. Occas. Pap. 183. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 32 pp.

Kozlowski, T.T. 1971. Growth and development of trees. vol. 2., chapter 5. New York: Academic Press. pp. 196-250.

McArthur, Geoffrey Morrison. 1980. Prediction of crown scorch in Pacific Northwest underburns. Seattle: University of Washington. 175 pp. Thesis.

Methven, Ian R. 1971. Prescribed fire, crown scorch and mortality: field and laboratory studies on red and white pine. Chalk River, Ontario Info. Rep. PS-X-31. Department of the Environment, Canadian Forestry Service, Petawawa Forest Experiment Station. 10 pp.

O'Neil, L.C. 1962. Some effects of artificial defoliation on the growth of jack pine (Pinus Banksiana Lamb.) Canadian Journal of Botany 40(2):273-280.

Redmond, D.R. 1959. Mortality of rootlets in balsam fir defoliated by the spruce budworm. Forest Science 5(1):64-69.

Romberger, J.A. 1963. Meristems, growth, and development in woody plants. Beltsville, MD: Tech. Bull. 1293. U.S. Department of Agriculture, Forest Service, Plant Industry Station. 214 pp.

Swaine, J.M. and F.C. Craighead. 1924. Studies on the spruce budworm (Cacoecia Fumiferana Clem.) Part 1. A general account of the outbreaks, injury and associated insects. Tech. Bull. 37. Dominion of Canada, Department of Agriculture. 91 pp.

Wade, Dale D. and R.W. Johansen. 1986. Effects of fire on southern pine: observations and recommendations. Gen. Tech. Rep. SE-41. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 14pp.

Wade, Dale D. and Darold E. Ward. 1975. Management decisions in severely damaged stands. Journal of Forestry 73(9):573-577.

Wakeley, Philip C. and Jose' Marrero. 1958. Five-year intercept as site index in southern pine plantations. Journal of Forestry 56(5):332-337.

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